bluejackets, which Captain Lang had taken the precaution to place in the immediate neighbourhood of the instruments; indeed both here and at Bathurst the natives were sufficiently well informed to watch the progress of the eclipse through smoked glass. The cause of the eclipse seems to have been ascribed to the Almighty, and not in any way associated with the presence of the astronomers. The members of the expedition themselves had no opportunity of studying the effect of the eclipse upon the brute creation, but trustworthy observers in Bathurst report that the usual state of alarm prevailed amongst fowls, cats, and other animals. Immediately after the eclipse the huts were partly dismantled, and the observers and their instruments were photographed by Prof. Thorpe, exactly as during the operations, the astonished natives meanwhile gathering in large numbers. After a short rest, the work of dismounting and packing the instruments was begun, and before sunset considerable progress had been made. By the evening of April 17, all was packed and safely aboard the *Alecto*, and the only material remnants of the expedition were waste paper and a slab of cement, prepared and inscribed by Lieutenant Hills, with the words, "British Eclipse Expedition, April 16, 1893." It is impossible to speak too highly of the assistance rendered to the expedition by the officers and men of the *Alecto*. As already stated, Lieutenant-Commander Lang made independent observations, with the assistance of Lieutenant Colbeck. Prof. Thorpe and Mr. Gray were assisted by Mr. Pym, and myself by Lieutenant Shipton and Chief Artificer Milligan, Lieutenant Hills by Dr. Moore, Sergeant Kearney by Sergeant Williams, and Mr. Collick and Mr. Forbes, by Mr. Willoughby, the engineer, and Mr. Murphy, one of the artificers.

The expedition left Fundium on April 18, and arrived at Bathurst on April 19, where H.M.S. *Blonde* was waiting under orders to convey the party to Grand Canary. Without this convenient arrangement, the expedition could not have left Bathurst before May 3 or 4. The homeward journey to England will be completed by a passage in the first available steamer.

THE ORIENTATION OF GREEK TEMPLES.[1]

THIS investigation is supplementary to Mr. Lockyer's examination of the orientation of the Egyptian temples, in the course of which he has cited passages translated from hieroglyphics, showing most distinctly that there was a connection between the foundation of those temples and certain stars. He has also shown that the structure of the temples demonstrates that the light from these stars must have been admitted at their rising or setting along the axis of the temples through the doorways, and that in certain temples the doorways have been altered in such a way as to follow the amplitude of the star as it changed, owing to the precession of the Equinoxes, and that in some cases a new temple had been founded alongside of an older one for the same purpose.

Although there does not seem to be any historical or epigraphical record of such a nature in Greece, the architectural evidence is not wanting. On the Acropolis of Athens there are two temples, both dedicated to Minerva, lying within a few yards of one another, both apparently oriented to the Pleiades, the older temple to an earlier position of the star group, and the other to a later one. At Rhamnus there are two temples almost touching one another, both following (and with accordant dates) the shifting places of Spica. In a temple at Ægina a doorway placed excentrically in the west wall of the cella was adapted for the observation of a setting star.

A clue is given for finding out the dates of the foundations of temples oriented to stars by means of the changes produced upon them by the precession of the Equinoxes; a movement which induces a divergence between the latitudes and longitudes of stars, and their places reckoned in declination and right ascension; so that after the lapse of 200 or 300 years a star which rose or set in the direction of the axis of a temple would have passed to a different amplitude, so as to be no more available for observation, as before, from the adytum.

In the earlier ages of Greek civilisation the only accurate measure of time by night was obtained by the rising or setting of stars, and these were more particularly observed when heliacal, or as nearly as possible to sunrise. For the purpose of temple worship, which was carried on almost exclusively at sunrise, the priests would naturally be very much dependent for their preparations on the heliacal stars as time warners.

The orientation of temples may be divided into two classes, solar and stellar. In the former the orientation lies within the solstitial limits; in the latter it exceeds them. In Greece there are comparatively few of the latter class.

In the lists of temples which follow, all the orientations were obtained from azimuths taken with a theodolite, either from the Sun or from the planet Venus. In almost every case two or more sights were observed, and occasionally also the performance of the instrument was tested by stars at night. The heights subtended by the visible horizon opposite to the axes of the temples were also observed.

The first list comprises twenty-seven intra-solstitial temples:

7	examples from	Athens.	1	example from	Sunium.
3	,,	Olympia.	1	,,	Corinth.
2	,,	Epidaurus.	1	,,	Bassæ.
2	,,	Rhamnus.	1	,,	Ephesus.
2	,,	Ægina.	1	,,	Platæa.
1	,,	Tegea.	1	,,	Lycosura.
1	,,	Nemea.	1	,,	Megalopolis.
1	,,	Corfu.	1	,,	Argos.

For all these the resulting solar and stellar elements are given, with the approximate dates of foundation, similarly to the following specimen, namely, that of the Temple of Jupiter at Olympia.

Olympia, lat. 37° 38′ *N.*

Temple of Jupiter	Orientation angle.		Stellar elements.	Solar elements.	Name of star.
	° ″ ′		° ″	° ′ ″	
	262 37 46	Amplitude, star or sun	8 33 0 N.	7 22 14 N.	
		Corresponding altitude	3 0 0 E.	1 42 0 E.	
		Declination	+8 40 0	+6 52 22	
		Hour angles	$6^h\ 11^m\ 37^s$	$7^h\ 34^m\ 52^s$	
		Depression of sun	...	14° 12′ 0″	
		Right ascension	$23^h\ 40^m\ 0^s$	$1^h\ 3^m\ 5^s$	
		Approximate date	B.C. 740	Apr. 6.	

This example has been selected from the rest of the list because this temple has been chosen for the purpose of showing the method of procedure in working out the elements from the observations, those, namely, of the orientation angle, and of the height of the visible horizon.

A few general remarks, however, seem required respecting the Sun's and star's altitude, and the Sun's depression when the star is to be observed.

For a star to be seen heliacally, it is necessary that the Sun should be just sufficiently below the horizon for the star to be recognised. According to Biot, Ptolemy, speaking of Egypt, has recorded this to be about 11°. But where, as generally in Greece, there are mountains screening the glow which at such times skirts the true horizon, it seems fair at any rate for a first magnitude star to consider 10° as sufficient. I have myself seen Rigel in the same direction as the Sun when elevated 2° 40′ above the sea horizon, the Sun being less than 10° below. Obviously an observer looking from a dark chamber in a well known direction would be more favourably situated.

It is proper to allow about 3° of altitude for a star to be seen above low clouds and the hazy glow which skirts the horizon. The Sun's light, however,, seems to be very effective at a lower altitude, and when he appears over a mountain of 2° or 3° altitude the angle may properly be reduced by 20′ or 25′, partly for refraction, and partly because a small segment only of the disc is sufficient for illumination.

The method I have pursued in working out the example of the Temple of Jupiter at Olympia is as follows.

The orientation angle, measured from the south point round by way of west and north, is 262° 37′ 46″, which is equivalent to an amplitude of +7° 22′ 14″. The eastern mountain subtends an angle of 2° 4′. For reasons above given, the solar altitude

---

[1] Abstract of a paper (read before the Royal Society on April 27), "On the Results of an Examination of the Orientation of a number of Greek Temples, with a view to connect these Angles with the Amplitudes of certain Stars at the time these Temples were founded, and an endeavour to derive therefrom the Dates of their Foundation by consideration of the changes produced upon the Right Ascension and Declination of the Stars arising from the Precession of the Equinoxes." By F. C. Penrose, F.R.A.S. Communicated by Prof. J. Norman Lockyer, F.R.S.

© 1893 Nature Publishing Group

may be taken as 1 42′, but that of the star, 3°. Combining these values with the latitude, viz., 37° 38′, and using the formula

$$\sin \delta = \cos \text{zen. dist.} \times \cos \text{colat} + \sin \text{zen. dist.} \times \sin \text{colat} \times \sin \text{ampl.},$$

we obtain for the star a declination of +7° 40′, and for that of the Sun +6° 52′ 22″. This latter, with the ecliptic obliquity of about 800 years B.C., determines the Sun's right ascension to have been 1h. 3m. 15s.

The next step is to inquire if there be any bright star or star group which, at a date consistent with archæological possibility, would have had a declination near to the above-named place, and would also have been heliacal.

Such a star would have required about 6h. 8m. to pass from 3° altitude to the meridian, and it would have required to have been about 1¼h. in advance of the Sun to allow it to be seen. The approximate R.A. of such star would therefore be about 23h. 40m., and its declination, as already stated, must be about 7° 40′ N.

For trials I have used a stereographic projection of the sphere taken on the pole of the ecliptic, but showing also R.A. hours and parallels of declination. Any place on this projection may be chosen and marked on a superimposed sheet of tracing paper, and then if the tracing paper is turned round upon the pole of the ecliptic as a centre, so that the straight line drawn upon it, which in the first instance joined the two poles marked on the projection is carried round to an angle equal to the amount of precessional movement under consideration, if there be a suitable star marked on the projection the point selected for trial will pass over it or near it, and after the star has been thus roughly pointed out the more exact calculations may be proceeded with. By this process in the case before us the tracing-paper mark coincided almost exactly with the place of α Arietis, and for this star the particulars were carefully computed which have been given in the list of elements.

It should be noticed that there are in every case of intra-solstitial temples four possible solutions of this step. The Sun's amplitude may be due either to the vernal or the autumnal place, and the star might have been heliacal either at its rising or setting. In every instance all these four alternatives have been tried by the preliminary search method, and in every case in temples of old foundation an heliacal star has resulted from one or other of the trials, but never more than one.

The star which has been found as above for the Temple of Jupiter is no other than the brightest star of the first sign of the Zodiac, and therefore peculiarly suited to that god. The same star is connected with the early temple of Jupiter Olympius at Athens.

In intra-solstitial temples, by the nature of the case, the stars are almost entirely confined to the Zodiacal constellations, and consequently suitable stars are very much limited in number.

Another very great limitation arises from the consideration that, to have been of any service as a time warner, the star must have been heliacal, and when these two limitations are taken into account it becomes improbable to the greatest degree that there should always have been a suitable star unless it had been so arranged by the builders of the temple.

In about two-thirds of the cases which I have investigated the dates deduced from the orientations are clearly earlier than the architectural remains now visible above the ground. This is explained by the temples having been rebuilt upon old foundations, as may be seen in several cases which have been excavated, of which the archaic Temple of Minerva on the Acropolis of Athens and the Temple of Jupiter Olympius on a lower site are instances. There are temples also of a middle epoch, such as the examples at Corinth, Ægina, and the later temples at Argos and at Olympia (the Metroum at the last named), of which the orientation dates are quite consistent with what may be gathered from other sources.

Besides the list of intra-solstitial temples already given I have particulars of five for which I have been unable to find an heliacal star. They are all known to be of recent foundation, when other methods of measuring time had been discovered. The solar axial coincidences were no doubt in all these cases connected with the great festivals of these temples. It was clearly the case in two of them.

At the Theseum at Athens the date was either October 10 or March 2. The *Thesea* festival is reckoned to have been on October 8 or 9. For the later Erechtheum the day would have been April 8 or September 3. The great festival of this temple is put down for September 3.

Leaving the solar temples, we find that the star which was observed at the great Temple of Ceres must have been Sirius, not used, however, heliacally—although this temple is not extra solstitial—but for its own refulgence at midnight. The date so determined is quite consistent with the probable time of the foundation of the Eleusinian Mysteries and the time of year when at its rising it would have crossed the axis at midnight agrees exactly with that of the celebration of the Great Mysteries.

It is reasonable to suppose that when, as in the case of Sirius at Eleusis, brilliant stars were observed at night, the effect was enhanced by the priests by means of polished surfaces.

Herodotus, speaking of a temple at Tyre (B. II, 44), says:—

"*Καὶ ἐν αὐτῷ ἦσαν στῆλαι δύο, ἡ μὲν χρυσοῦ ἀπέφθου, ἡ δὲ σμαράγδου λίθου, λάμποντος τὰς νύκτας μέγαθος.*"

(Two shafts, one of pure gold, the other of emerald, which shone remarkably at night.)

Of a list of seven extra-solstitial temples which are named, five are more particularly noticed, viz. :—

A temple at Mycenæ and one near Thebes, which are built nearly north and south, but which probably, as was the case at Bassæ, had eastern doorways. The star, α Arietis, which suits the first, seems to point out the dedication of this temple to Jupiter. The other is very remarkable, and connects the Bœotian Thebes with the great Egyptian city; the star was γ Draconis. Thebes was called the City of the Dragon, and tradition records that Cadmus introduced both Phœnician and Egyptian worship. Three of the temples lay more nearly at an angle bisecting the cardinal points; these are Diana Propylæa at Eleusis, a small temple (not yet named) lately discovered at Athens, and the Temple of Venus at Ancona, recovered by means of the walls of a church built upon its traditional site. In these temples the star observed at the first seems to have been Capella, the time of the year when it shone axially at midnight agreeing with that of the celebration of the Little Mysteries, and in the other two the star was Arcturus.

EXPLORATIONS IN THE KARAKORAM.

MR. W. M. CONWAY gave an account of his recent exploring expedition in the Karakoram mountains at the last meeting of the Royal Geographical Society. The paper was illustrated by lantern slides, and a series of paintings by Mr. McCormick, who accompanied the expedition, was also exhibited. Mr. Conway said :—We left Srinagar on April 13, 1892, and came to Gilgit. Arrived at Gilgit we found the condition of the mountains, from a climber's point of view, too backward for our purposes. We therefore spent a month in mapping and exploring the fine Bagrot Valley, which slopes southwards from Rakipushi and its immediate neighbours along the main ridge. We hoped to be able to force a passage over this ridge into Nagyr ; but the persistent bad weather baulked our efforts when they were on the point of succeeding. When the traveller has emerged from the inhospitable defiles which sunder the valley of Hunza Nagyr from Gilgit, and has climbed the vast ancient moraines near Tashot, which form the final rampart of the fertile basin (fertile, of course, only by reason of artificial irrigation of admirable complexity and completeness), he stands surrounded by an astonishing view. The bottom of the valley is, as usual, deeply filled by *débris*, whose surface is covered by terraced fields, faced with cyclopean masonry, and rich with growing crops and countless fruit trees. The mountains fling themselves aloft on either hand, with astounding precipitancy, as it were into the uttermost heights of heaven ; so steeply, in fact, that a spring avalanche falling from the summit of Rakipushi on the south must almost reach the bottom of the valley. Rakipushi is 25,500 feet high; the Hunza peak is about 24,000 feet high. Their summits are separated by a distance of 19 miles. Both mountains are visible from base to summit at one and the same time from the level floor of the valley between them, which is not more than 7000 feet above the sea. No mountain view that I saw in the Karakorams surpasses this for grim wonder of colossal scale, combined with savage grandeur of form and contrast of smiling foreground.

Having been beaten back on June 24 from an attempt to

© 1893 Nature Publishing Group